IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re:	Application No. 10/694,960	*Confirmation No. 4443*
Filed:	October 28, 2003	
Applicants:	Isabelle Laye et al.	
Title:	PROCESS CHEESE CONTAINING INCREASED LEVELS OF WHEY PROTEIN	
Art Unit:	1794	
Examiner:	Leslie A. Wong	
Attorney Docket:	1410/79708	
Customer No.:	22242	

Mail Stop AMENDMENT
Commissioner for Patents
P. O. Box 1450
Alexandria, Virginia 22313-1450

DECLARATION OF DR. FU-I MEI
UNDER 37 C.F.R. § 1.132

I, DR. FU-I MEI, declare as follows:

1. I am one of the inventors of the subject matter claimed in the above-captioned patent application, U.S. Patent Application Serial No. 10/694,960. I have personal knowledge of the matters stated herein.

2. The assignee of the above-captioned application is Kraft Foods Holding Inc., which is now Kraft Foods Global Brands LLC ("Kraft Foods"). I am currently employed by Kraft Foods as a Program Manager and have worked in the food science field for about 17 years. I have a Ph.D in Food Science and Nutrition from Ohio State University.

3. I have read and understand the newly cited reference Gupta et al., "Firmness and Melting Quality of Processed Cheese Foods with Added Whey Protein Concentrates," LAIT, Vol. 73, pp. 381-388 (1993) [hereinafter "the Gupta 1993 reference"].

4. It is my understanding that the Office Action dated June 2, 2008 suggests the Gupta 1993 reference describes a processed cheese having a casein-to-whey ratio lower than 3:1 with a melting point between about 105°F and 150°F. This Declaration addresses these contentions in the Office Action.

5. The Gupta 1993 reference describes a study in which a portion of the cheese solids in processed cheese is replaced with whey protein concentrate (WPC) and various parameters, including melting quality, were measured. (Gupta 1993, p. 382.) The Gupta 1993 reference, however, uses a non-standard or indirect test method to evaluate melting quality. Gupta evaluated the melting quality indirectly by measuring the average percent decrease in the height of a cylinder of cheese (17 mm high by 17 mm diameter) after about 15 minutes at a temperature of about 100-102°C. (*Id.* at 383.) The results of Gupta's melting quality study are provided in FIG. 3 of the Gupta 1993 reference. (*Id.* at 386.) In the Gupta 1993 reference, a control processed cheese, a process cheese having 10 percent of the cheese solids replaced with WPC, and a process cheese having 20 percent of the cheese solids replaced with WPC were evaluated. As explained in the Gupta 1993 reference, "[a]t 44% moisture content the controlled and processed cheese foods with 10 and 20% cheese solids replaced by those of WPC showed = 90.5, 60.5, and 19% decrease in cheese cylinder height." (*Id.* at 385-86.) Regarding those results, the Gupta 1993 reference further stated "[a]n increased amount of whey protein concentrates and trisodium citrate improved the firmness in a highly significant manner ($P > 0.01$), ***but had a highly significant deleterious effect ($P > 0.01$) on the melting quality of processed cheese foods***." (*Id.* at 381, emphasis added.)

6. Gupta did not measure or report the melting quality by determining the specific melting points of his processed cheeses. Rather, the Gupta 1993 reference evaluated the melting quality of the process cheese using the indirect or non-standard test described

above (*i.e.*, the decrease in cheese cylinder height upon heating). Therefore, to better compare the claimed cheese to the cheese described by the Gupta 1993 reference, we duplicated Gupta 1993's control cheese, 10 percent replacement cheese, and 20 percent replacement cheese and evaluated the melting point/softening point using the test method as described in the present application. That is, we duplicated the Gupta 1993 samples and measured the melting point/softening point using a Mettler Dropping Point Furnace and a Mettler processor. (*See* present specification, p. 13, lines 29-30.) By duplicating Gupta's samples, we were able to measure the melting points of Gupta's cheeses for a more direct comparison to the claimed cheese by using a more accurate and direct test method provided by the Mettler dropping point system.

7. The Gupta 1993 reference stated that the processed cheese used for the melting quality evaluations were prepared according to the procedures described in Gupta et al., "Processed Cheese Foods with Added Whey Protein Concentrates," LAIT, Vol. 72, pp. 201-212 (1991) [hereinafter "the Gupta 1991 reference," attached hereto as Exhibit A]. (*See* Gupta 1993, p. 382.) Therefore, I also reviewed the Gupta 1991 reference in order to duplicate as closely as possible the processed cheese samples used in the melting quality evaluation of the Gupta 1993 reference.

8. To duplicate the Gupta processed cheeses, we first had to make the control processed cheese with no replacement of WPC by blending Cheddar cheese, emulsifier, and water to a target moisture content. As explained in the Gupta 1991 reference, the processed cheese was made from a blend of old Cheddar cheese and young Cheddar cheese. (Gupta 1991, p. 202.) Therefore, we obtained 1.5 to 2 month old Cheddar cheese (*i.e.*, young) supplied from Twin County Dairy, Iowa and 5 to 6 month old Cheddar cheese (*i.e.*, old) supplied from Jerome Cheese Company, Idaho to use in the blend.

9. Gupta did not provide the complete compositional data of the Cheddar cheese used to form his processed cheese samples. Therefore, we assumed the Cheddar cheese had a total solids of about 65 percent and the composition as generally provided in Table 1 below,

which is consistent with the Cheddar cheese as typically supplied from our vender and is also consistent, on a dry basis, with the standard of identity for Cheddar cheese as defined in 21 C.F.R. § 133.113. This compositional information is needed in order to formulate the processed cheeses to the correct moisture contents.

Table 1: Composition of Cheddar Cheese

Ingredient	Amount, %	Solids, %
Water	35	-
Protein	25	65
Fat	35	
Other	5	

10. Next, we selected a moisture content of about 43 to about 45 percent for the formed process cheese and used the same 3% trisodium citrate as emulsifier as Gupta used for his melting quality samples as explained in FIG. 3 of the Gupta 1993 reference. The moisture content falls within the ranges of the three samples Gupta evaluated for melting quality in FIG. 3 of the Gupta 1993 reference.

11. To make the control processed cheese from a Cheddar cheese blend (young and old) having the composition of table 1, about a 45 percent moisture content, a 3 percent trisodium citrate level, and no added whey, we prepare a mixture as provided in Table 2 below and cooked the mixture into a homogeneous mass at a temperature of about 179°F for about 4 minutes. The Gupta 1991 reference described that he cooked the cheeses at about 82°C (179°F) for 3-4 minutes. (Gupta 1991, p. 204.) The formulation of table 2 resulted in a control processed cheese having a composition as summarized in Table 3 below and a moisture content of about 44.6 percent. The protein in this control cheese consisted of about 99% casein, which results in a casein-to-whey ratio of the control of about 99:1.

Table 2: Control Cheese Formula

Ingredient	Amount	Ingredient	Actual Control Amount
Cheddar Cheese	80 %	Cheese Blend	32 lb*
TSC	3 %	TSC	544.3 g
Added Water	17 %	Water	7.5 lb

* 22 lbs of young cheese and 10 lbs of old cheese

Table 3: Composition of Control Process Cheese

Ingredient	Amount, %
Water	45
Protein	20%
Fat	28%
TSC	3%

12. Next, we prepared the 10 percent and 20 whey replacement samples as described in the Gupta 1991 and Gupta 1993 references. As stated in the Gupta 1991 reference, the amount of WPC added to the processed cheese was based on the formula defined on page 202 of that reference. For convenience, the formula is reproduced below.

$$\text{amount of WPC (g)} : \frac{a \times b}{c}$$

where a = percentage of total solids of cheese
b = amount of cheese to be replaced
c = % total solids of WPC

13. As explained more fully below, because Gupta used a non-commercially available WPC, did not provide the amount of water he added into his formulations, and did not report the amount of water evaporated during cooking, we estimated our formulations for

the 10 percent and 20 percent whey replacement samples by first calculating the amount of whey and lactose in Gutpa's processed cheeses based on the data in the Gupta 1991 reference and a 45 percent moisture level. We then back calculated what amount of commercially available whey and water were needed in the actual formulations to achieve similar levels of whey and casein in the final 10 and 20 percent replacement processed cheeses. This process is summarized below.

14. First, we selected the WPC that provided the most whey into the processed cheese. The Gupta 1991 reference in Table 1 on page 203 lists several WPCs in which Gupta used to replace some of the cheese solids in his processed cheeses. However, the Gupta 1993 reference did not explain which WPC of Table 1 was used in his melting quality study of FIG. 3. (*See*, the Gupta 1993 reference, pp. 383 and 385-386.) Therefore, we selected WPC 26.1 from Gupta's table on page 203 as a reference because this WPC had the highest total solids and the highest total protein (relative to solids) of the WPCs used in the Gupta 1991 study. In this manner, we used the WPC that would provide the highest level of whey replacement into the processed cheeses. Based on the data in Table 1 (p. 203) of the Gupta 1991 reference, the WPC 26.1 had about 19.9 percent protein, about 73.9 percent water, about 26.1 percent total solids, and about 5.8 percent total lactose.

15. Second, to determine how much casein and whey are in Gupta's 10 and 20 percent replacement cheeses, we estimated what the casein and whey would be for a theoretical 100 gram batch of Gupta's cheese with either 10 or 20 percent of the cheese replaced with WPC 26.1 using Gupta's formula of page 203 of the 1991 reference.

16. As explained in paragraph 7 above, "a" or the assumed percent solids of Gupta's Cheddar Cheese is about 65 percent.

17. The amount of cheese to be replaced ("b") is either 10 or 20 percent of the Cheddar cheese in the formula. A theoretical 100 gram batch of Gupta's cheese would have 80 grams of Cheddar per Table 2 above. As a result, "b" or the weight in grams of the cheese to be replaced in Gupta's theoretical cheese is either about 8 grams for a 10 percent

replacement (*i.e.*, 80 grams x 10%) or about 16 grams for a 20 percent replacement (*i.e.*, 80 grams x 20%).

18. Regarding the denominator of the above formula or "c" (*i.e.*, the percent solids of the WPC), the Gupta 1991 reference in Table 1 on page 203 states that WPC 26.1 has 26.1 percent solids.

19. Based on the information in paragraphs 12-18 above, we estimated the following casein and whey amounts in Gupta's processed cheese with either 10 or 20 percent replacement of cheddar with WPC 26.1 using the formula on page 202 of the Gupta 1991 reference. These calculations are summarized below in Table 4.

Table 4: Calculated Amounts of WPC Replacement Based on Gupta Formula

	"a" % Solids of Cheddar	"b" Amt of Cheddar to Replace	"c" % Solids of WPC Blend	Calculated Amt of WPC in Theoretical Gupta cheese
10 % Replacement	65%	8 grams	26.1%	19.9 grams
20 % Replacement	65%	16 grams	26.1%	39.8 grams

20. Based on the information in Table 4 above, we then estimated the casein and whey amounts in each theoretical Gupta cheese containing the added amounts of WPC 26.1. This calculation is provided in Table 4A below.

Table 4A: Calculated Casein and Whey amounts in Theoretical Gupta Cheese

Ingredient	20 Percent Cheese	10 Percent Cheese
Cheese Protein (casein)	(80-16) grams x 25% protein = 16 gram casein	(80-8) grams x 25% protein = 18 grams casein
Whey protein	39.8 grams x 19.9 % protein = 7.92 grams whey	19.9 grams x 19.9 % protein = 3.9 grams whey
Total protein in WPC processed cheese	16 grams casein + 7.92 grams whey = 23.92 total grams protein	18 grams casein + 3.9 grams whey = 21.9 grams total protein
% casein	67%	82%
%whey	33%	17%

21. Gupta's WPC 26.1 does not appear to be a commercially available WPC. Thus, to prepare the actual WPC replaced cheese based on Gupta's disclosures, we back calculated our cheese composition to provide the same levels of casein and whey as calculated in Table 4A above, but using commercially available WPCs.

22. To produce the actual cheese, we blended a commercially available WPC 80 (*i.e.*, about 80 % whey protein and about 96 % solids from Glanbia Foods Inc., Idaho) and WPC 34 (*i.e.*, about 34 % whey protein and about 96 % solids from First District Association, Minnesota). To duplicate the casein, whey, and lactose amounts in Gupta's processed cheese using WPC 26.1, our total WPC blend included about 68 percent WPC 80 and about 32 percent WPC 34, which duplicates equivalent amounts of protein and lactose levels provided to the processed cheese as obtained from Gupta's WPC 26.1 used in the Gupta 1991 reference. This blend of WPC 80 and WPC 34 had a total solids content of about 96 percent. Water was then added to the formula to make the desired batch size and moisture content in the final cheese.

23. Based on the amount of whey calculated above in table 4A, we prepared 40 pound batches of the processed cheeses to a moisture content of about 43 to about 45 percent with 3 percent trisodium citrate emulsifier. Our formulas are provided below in Table 5, which duplicate as closely as possible the same levels of casein and whey as calculated in the 10 percent and 20 percent replacement samples as used by Gupta in his evaluation of melting quality in FIG. 3 of his 1993 study (*See* Table 4A above). The 10 percent and 20 percent replacement cheeses were made similar to the control cheese described above in paragraph 11.

Table 5: Actual Formulas of 10 percent and 20 percent Processed Cheeses

Ingredient	10%	20%
WPC 80	1.8 lb	3.5 lb
WPC 34	0.85 lb	1.7 lb
Cheddar Cheese	28.8 lb*	25.6 lb**
TSC	544.3 g	544.3 g
Added Water	7.4 lb	8.0 lb
Moisture	44%	43%
% Casein	79%	63%

* 19.8 lbs of young cheese and 9.0 lbs of old cheese
** 17.6 lbs of young cheese and 8.0 lbs of old cheese

24. In order to compare how closely we duplicated Gupta's samples, we then tested the control, 10 percent replacement, and 20 percent replacement cheeses based on the indirect melt quality evaluation described by Gupta in his 1993 paper by evaluating the percent decrease in the height of a cylindrical cheese piece (17 mm diameter and 17 mm height) after heating the cheese at 100 to 102°C for 15 minutes. (*See* the Gupta 1993 reference, p. 383.) The results of this evaluation are provided in Table 6 below. For each sample, we tested 12 different cylinders of cheese.

Table 6: Gupta Melting Quality Evaluations

Sample	Measured Height Before heating, mm	Measured Height After Heating, mm	Avg Height After Heating, mm	Avg Decrease in Cylinder Height, mm	Decrease Cylinder Height, %	Decrease in Cylinder Height Reported by Gupta 1993, p. 386 at 45% moisture
Control	17	2, 3, 2, 3, 2, 2, 3, 3, 3, 3, 3, 3	2.7	14.3	84.2	~90-91%
10%	17	7, 11, 8, 11, 11, 11, 10, 13, 10, 9, 11, 11	10.3	6.8	39.7	~65%
20%	17	11, 14, 9, 10, 13, 14, 13, 15, 15, 11, 11, 14	12.5	4.5	26.5	~20-22%

25. To evaluate how closely we duplicated the samples of Gupta's references, we compared the percent decrease in cylinder height we measured to those reported by the Gupta 1993 reference in FIG. 3 at 43 to 45 percent moisture (*See* the Gupta 1993 reference, p. 386.). Given the variability inherent in this non-standard test method used by Gupta, it is our opinion that the samples we prepared fairly closely duplicated those described in the Gupta 1991 reference and the Gupta 1993 reference due to the similarities between the cylinder height reductions upon heating. Thus, we concluded the assumptions we made discussed above were reasonably appropriate to duplicate as best we can the processed cheeses described by the Gupta 1991 and the Gupta 1993 references.

26. Next, based on the amount of added whey in each of the samples prepared using the Gupta refrences, we calculated the casein-to-whey ratio for each of the Gupta samples. This data is provided below in Table 7.

Table 7: Actual Casein-to-Whey Ratios of Prepared Gupta Processed Cheese

Sample	Actual % Casein	Actual % Whey	Actual Casein:Whey Ratio	Ratio Within Range Defined By Claims
Control	99	1	99:1	NO
10%	79	21	3.8:1	NO
20%	63	37	1.7:1	YES

27. As shown in Table 7 above, neither the control nor the 10% sample fell within the casein-to-whey ratio defined by the claims of the present application (*i.e.*, 1.1 to 3.1), but the casein-to-whey ratio of the 20 percent sample did fall within the range as defined by the present claims.

28. Next, we evaluated each of the actual Gupta processed cheeses we prepared using the Mettler Dropping Point Furnace and the Mettler processor to determine the melting point/softening point as defined in the present application. The results are provided in Table 8 below with reference to the casein-to-whey ratios.

Table 8: Mettler Dropping Point Melting Data

Sample	Actual Melting Point Based on Mettler Dropping Point Furnace	Actual Casein-to-Whey
Control	47.8°C (118°F)	99:1
10%	no melt >100°C (>212°F)	3.8:1
20%	no melt >100°C (>212°F)	1.7:1

29. As shown in Table 8 above, only the 20 percent processed cheese sample prepared based on the disclosure of the Gupta 1993 reference and the Gupta 1991 reference had a casein-to-whey ratio within the ranges defined by the present claims (*i.e.*, about 3:1 or lower). This sample, however, exhibited a Mettler Dropping Point Melting Point *far* outside our claimed range of about 105°F to about 150°F. Indeed, this sample did not even melt at all using the Mettler system. As a result, the claimed cheese exhibits melting points that are much lower than what is expected based on the disclosures of the processed cheeses in the Gupta references. Moreover, the Gupta 10 percent and 20 percent cheeses did not even have a melting point of conventional processed cheeses.

30. I hereby declare that all statements made herein of my own knowledge are true, and that all statements made herein on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity or enforceability of the application or any patent issued thereon.

December 2, 2008

Date

Dr. Fu-I Mei

EXHIBIT A

Lait (1992) 72, 201-212

Original article

Processed cheese foods with added whey protein concentrates

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Summary — The technique for the manufacture of processed cheese foods has been standardized with 20% of their cheese solids replaced by whey protein concentrates (WPC). Among the different emulsifiers tested (a combination of trisodium citrate and disodium phosphate and trisodium citrate alone) only trisodium citrate was able to produce a smooth texture. Trisodium citrate at 2.5% and with a moisture content of 45.2% resulted in processed cheese foods with the best sensory characteristics (out of a total of 7, the scores were as follows: flavour, 5.5; consistency, 6; appearance, 5.8; overall acceptability, 5.6). WPC with a high UF concentration (26.1% TS) and low calcium content (0.7% on dry basis) were found to be the most suitable for incorporation in processed cheese foods. Diafiltration of WPC had a negative effect as regards suitability for the product. The standardized technique for processed cheese manufacture is: take a mixture of 25% 6.5–7.5-month-old and 55% 2–3-month-old grated cheddar cheese), WPC equivalent to 20% of cheese solids, dry salt and water; heat the contents with thorough stirring by indirect steam heating. At a temperature of about 49 °C, sprinkle 2.5% dry trisodium citrate and continue heating until the temperature reaches 82 °C, and maintain this temperature for 3–4 min.

processed cheese foods / whey protein concentrate addition / emulsifying salts

Résumé — Fabrication de fromage fondu avec ajout de concentrés de protéines de lactosérum. *Un procédé de fabrication de fromage fondu basé sur le remplacement de 20% de la matière sèche fromagère par un concentré de protéines de lactosérum (CPL) a été développé. Parmi les différents émulsifiants testés (citrate trisodique seul ou citrate trisodique + phosphate disodique), seul le citrate trisodique était à même de donner une texture lisse au produit. Les meilleures caractéristiques sensorielles (sur 7, les scores étant pour la flaveur : 5,5, la consistance: 6, l'apparence : 5,8, l'acceptabilité générale : 5,6) étaient obtenues avec 2,5% de citrate trisodique et une teneur en eau de 45,2%. Une forte concentration des CPL (26,1% de la matière sèche) et une faible teneur en calcium (0,7% de la matière sèche) facilitaient leur incorporation dans le mélange de fonte. Par contre, la diafiltration conduisait à un effet inverse. Le procédé de fabrication développé était le suivant : addition dans le pétrin de fromage cheddar rapé (mélange de 25% de fromage âgé de 6,5–7,5 mois, et 55% de fromage âgé de 2–3 mois), d'une quantité de CPL équivalente à 20% de la matière sèche du fromage, de sel sec et d'eau; chauffage du contenu par la paroi avec agitation régulière. Lorsque la température atteignait 49 °C, saupoudrage de citrate trisodique sec à 2,5%; poursuite du chauffage jusqu'à 82 °C et maintien de cette température pendant 3 à 4 min.*

fromage fondu / concentré de protéine de lactosérum / sels émulsifiants

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INTRODUCTION

A fairly large amount of processed cheese foods is prepared in the USA, Russia and many East European countries, but much work still has to be done on standardizing this product. There is very little information available on processed cheese foods with added whey protein concentrates (Georgakis, 1975; Kairyukshtene *et al*, 1978).

Whey has long been known to contain proteins of high nutritional value, but their use in human nutrition has been complicated by the high lactose and low protein content (Forsum, 1975). Ultrafiltration (UF) technology developed over the last 2 decades has now made possible the production at a relatively economical price of whey protein concentrates (WPC) which are low in lactose. With this new technology, it has also become possible to produce WPC with different physicochemical and functional properties for applications in different food systems.

Processed cheese is a complex system composed of protein, fat, mineral salts and other ingredients. Its properties are affected by many variables such as composition and nature of the initial natural cheese, the nature and amount of the emulsifying agents, the manufacturing procedure and additional factors (Caric *et al*, 1985). The emulsifier plays a very important role in producing desirable body and texture characteristics, and melting and slicing properties in the finished cheese products. Three major categories of extensively employed emulsifying salts are: citrates, monophosphates and polyphosphates (Kosikowski, 1982; Shimp, 1985).

In the present investigation, an attempt has been made to add WPC in the formulation of processed cheese foods and to standardize their manufacturing process.

MATERIALS AND METHODS

Manufacture of WPC

Different types of WPC (table I) were prepared by ultrafiltration (UF) of Tilsit cheese whey on an UF module with a hollow fiber membrane (Romicon, polysulfone membrane type pM 50, fiber inside diameter 1.1 mm, effective membrane area 2.5 m^2, molecular weight cutoff, 50 000) by varying; a) preheating treatment of whey (holding period, 30 min); b), UF temperature; c), level of UF concentration; and d), diafiltration treatment as described earlier (Gupta and Reuter, 1987). These WPC were put in polythene bags and kept at –20 °C till used.

Manufacture of processed cheese/ processed cheese foods

A blend of 25% old Cheddar cheese (6.5–7.5 months old) and 75% young Cheddar cheese (2–3 months old) was used for processed cheese manufacture. For processed cheese foods, part of the young cheddar cheese solids were replaced by WPC solids. The amount of WPC for replacement of Cheddar cheese was calculated as follows:

$$\text{amount of WPC (g)} : \frac{a \times b}{c}$$

where a =% total solids of young Cheddar cheese; b = amount of young cheese to be replaced (g); c = % total solids of WPC.

Young and old Cheddar cheeses were kept at room temperature overnight, cleaned, quartered and grated. The calculated amount of Cheddar cheese, WPC, salt and water for preparing 1 kg product were added in a 2.5-l semi-spherical stainless steel kettle. The water added also included the subsequent water loss (175 ml) due to evaporation during heat processing of cheese. The contents in the kettle were heated with continuous stirring and scraping of the surface. As the temperature approached 49 °C, the emulsifying salt either after dissolving in water or in dry form was slowly added and thoroughly mixed.

Table I. Different whey protein concentrates used in processed cheese foods.
Caractéristiques des concentrés de protéines de lactosérum utilisés dans les fromages fondus.

Temperature (°C)		*Diafiltration*	*TS (%)*	*Protein/ TS (%)*	*Fat/TS (%)*	*Ash/TS (%)*	*Ca/TS (%)*	*Lactose/ TS (%)*	*pH*	*Type of WPC*
pre-heating	*UF*									
68–72	50	No	18.3	63.8	2.2	6.1	1.3	29.5	6.5	WPC (18.3)
40	50	No	19.5	67.9	2.1	4.5	0.6	27.2	6.5	WPC (19.5)
68–72	60	No	20.1	65.1	2.5	6.8	1.4	25.4	6.5	WPC (20.1)
45	45	No	25.1	74.9	2.5	4.1	0.8	22.5	6.5	WPC (25.1)
40	50	No	26.1	76.3	2.4	4.0	0.7	22.4	6.5	WPC (26.1)
25	25	Yes	13.0	72.6	2.4	3.9	0.6	20.1	6.7	WPCD (13.0)
68–72	60	Yes	16.5	74.1	2.5	5.8	1.7	15.2	6.7	WPCD (16.5)
68–72	60	Yes	19.7	78.9	2.6	5.7	1.8	12.2	6.7	WPCD (19.7)
68–72	50	Yes	23.6	82.6	2.7	5.3	1.6	9.5	6.7	WPCD (23.6)

Heating was continued to 82 °C, and the temperature maintained for 3–4 min. The entire processing period lasted 15 min. The hot product was then immediately poured into plastic cups (Bellaplast, Art No 810) which were secured with airtight lids. Cups were maintained overnight at 18 °C and then moved to cold store maintained at 6 °C.

Chemical analysis

WPC were analysed for their chemical composition as follows:

- total solids by gravimetric procedure;
- protein by the Kjeldahl method (AOAC, 1970), protein factor 6.38;
- fat by the Gerber method;
- ash by AOAC (AOAC, 1970);
- calcium and lactose using a Technicon Autoanalyser;
- pH using a pH meter (E 5000, Metrohm, Switzerland).

Cheddar cheese, processed cheese and processed cheese foods were analysed for moisture by gravimetric method.

Sensory evaluation of processed cheese foods/processed cheeses

Products were evaluated for flavour, consistency, appearance and overall acceptability by a 7-member panel. The cheese samples were kept at 18 °C overnight preceding sensory evaluation. The order of testing was randomized. To assist the judges in describing defects, the scores sheet included a list of suggested flavour, consistency and appearance defects. The judges were asked to give an overall score ranging between 1–7, where 7 = excellent, 6 = very good, 5 = good, 4 = fair, 3 = poor, 2 = very poor and 1 = extremely poor.

Statistical analysis

The data were analysed, wherever necessary, for 2-way analysis of variance with interaction and 1-way analysis of variance without interaction as per the procedure of Snedecor and Cochran (1967). Critical difference was also calculated from the *t*-value.

RESULTS

Effect of different emulsifying salts

Processed cheese foods (43–44% moisture) were prepared by replacing 7–20% of young cheese solids with WPC solids. During heat processing, there was no free fat release as was otherwise the case when no WPC was added. This indicated sufficient emulsification of fat even with 7% WPC. Flavour and appearance scores of the final food were on average 5, but the texture was chalky and sandy, as a result of which the consistency score was below 4 and the total acceptance score on average 4. The use of diafiltered WPC (WPCD, 23.6) with lactose/TS as low as 9.5% did not prevent the sandiness in the processed cheese foods, suggesting that lactose was not responsible for the defective texture.

Emulsifying salts (Joha: S-8, 1.2% and S-10, 0.8%), which are widely utilized in Germany, when used at the 2% level did not improve the consistency of the processed cheese foods with added WPC. Trisodium citrate and disodium phosphate emulsifiers added in equal proportion at 2.0, 2.5 and 3.0% levels also failed to improve the texture of cheese foods. The sandiness appeared in all processed cheese food samples even with a low 5% WPC solids.

Other measures such as addition of WPC 0.5 h before heat processing, just before processing or during heat processing had no effect on preventing sandy or chalky texture in cheese foods. An attempt to manufacture processed cheese foods in

a Stephan Universal Machine, employing a high-speed cutting device (3 000 rpm) and direct steam injection, succeeded in giving a smooth textured product, but only under conditions of more than 55% moisture. At that high moisture level, the cheese food was very weak in body and unacceptable to the judges.

Lastly, an attempt was made using trisodium citrate alone as emulsifier, as is done in India. This emulsifier when used at the 3% level prevented the development of a sandy texture in the cheese foods even when up to 25% cheese solids were replaced with WPC solids (table III). The stage at which WPC was added, as mentioned earlier, did not affect the quality of the final product.

Effect of different WPC

Table II shows the effect of different WPC replacing 10% cheese solids on the sensory scores of processed cheese foods. Different WPC affected the flavour and consistency scores of processed cheese foods highly significantly ($P < 0.01$). Amongst the different WPC used, WPCD (16.5) imparted a significantly better flavour score (CD = 0.253) to the final product, while WPC (18.3) and WPC (26.1) resulted in significantly better consistency scores (D = 0.335) compared to WPCD (13.0). For a higher level of WPC incorporation, a higher UF concentration was necessary to bring the moisture content to within acceptable upper limits in processed cheese foods. To avoid extra moisture, salts and emulsifying salts were added in dry form, and this did not affect the sensory quality of the final product.

The addition of diafiltered WPC tended to have a negative effect on the consistency of processed cheese foods. The effect was more prominent at higher levels (15–25%) of WPC addition (table III). When WPCD (23.6) and WPC (26.1) were com-

Table II. Average sensory scores of processed cheese foods with 10% cheese solids replaced with different WPC.
Influence du remplacement de 10% de la matière sèche fromagère par différents CPL sur les caractéristiques sensorielles des fromages fondus.

Characteristics of processed cheese foods	*Type of WPC used*			
	WPC (18.3)	*WPC (26.1)*	*WPCD (13.0)*	*WPCD (16.5)*
Moisture (%)	43.5	44.9	45.2	45.3
Flavour	4.9	4.9	5.1	5.4
Consistency	5.9	5.8	5.2	5.6
Appearance	5.8	5.9	6.0	5.9
Overall acceptability	5.8	5.8	5.4	5.6

Table III. Effect of diafiltered WPC on the average sensory scores of processed cheese foods.
Effet de la diafiltration des CPL sur les caractéristiques sensorielles des fromages fondus.

Characteristics of processed cheese foods	*WPCD (23.6)*			*WPC (26.1)*		
	15%	*20%*	*22.5%*	*20%*	*22.5%*	*25%*
Moisture (%)	45.1	46.1	47.6	47.2	46.9	47.4
Flavour	5.8	4.5	3.2	6.0	6.0	5.8
Consistency	6.0	3.5	2.5	5.5	5.1	4.5
Appearance	6.0	5.8	5.1	6.0	5.2	5.0
Overall acceptability	6.0	4.1	3.2	5.8	5.5	5.1

pared at 20 and 22.5% levels of addition in processed cheese foods, their flavour, consistency and overall acceptability scores were observed to be affected highly significantly ($P < 0.01$) with the type and levels of WPC addition. The higher level and diafiltration of WPC showed substantial adverse effects on the sensory quality of processed cheese foods.

Effect of different moisture content

Figure 1 illustrates the consistency scores of processed cheese foods with different moisture content when prepared with 3% trisodium citrate emulsifier and a varying amount of cheese solids replacement with WPC. It was observed that for better consistency (score, 5.7–6.0), the control sample had to have 41.4% moisture, whereas for the same good consistency the moisture content in processed cheese foods had to be increased proportionally with the increase of WPC addition. With 10, 15 and 20% cheese solids replacement with WPC, processed cheese foods scored 5.7–6.0 in the vicinity of 44.9, 45.9 and 46.7% moisture content respectively. A higher moisture level than this resulted in a softer product while a lower moisture level made the body of the product harder and brittle.

Effect of different levels of trisodium citrate

In order to determine the optimum level of trisodium citrate, processed cheese foods were prepared with 1.5, 2.0, 2.5 and 3.0% trisodium citrate. The amount of trisodium citrate added affected all the sensory indices of processed cheese foods (table IV) highly significantly ($P < 0.01$). Processed cheese foods with 2.5 and 3.0% trisodium citrate were judged to be much better in consistency, appearance and overall acceptability than with 1.5 and 2.0% trisodium citrate. On a flavour score basis, the product with 2.5% trisodium citrate was judged to be best. It was observed that at

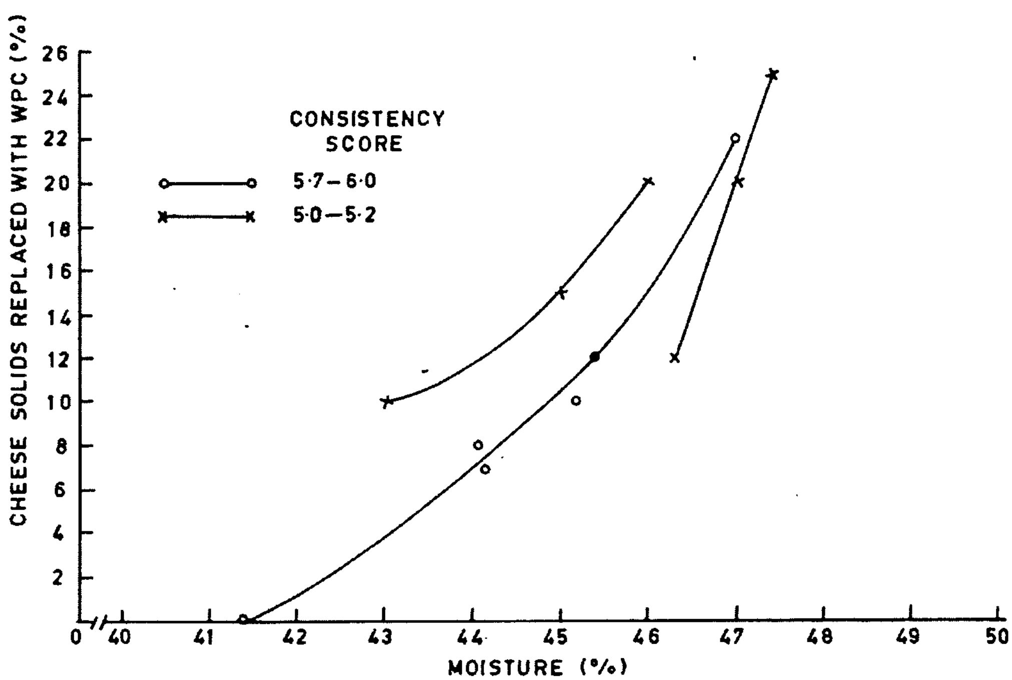

Fig 1. Consistency score of processed cheese foods as affected by different amounts of WPC and moisture.

Consistence des fromages fondus suivant l'apport de CPL et l'humidité.

Table IV. Effect of trisodium citrate level on the average sensory scores of processed cheese foods.
Effet du taux de citrate trisodique sur les caractéristiques sensorielles des fromages fondus.

Characteristics of processed cheese foods	*Trisodium citrate (%)*			
	1.5	*2.0*	*2.5*	*3.0*
Moisture (%)	44.0	44.5	44.6	45.3
Flavour	4.8	4.8	5.3	4.9
Consistency	3.1	4.2	5.2	5.1
Appearance	4.1	4.3	5.9	5.8
Overall acceptability	4.1	4.2	5.4	5.1

1.5 and 2% level of trisodium citrate, the product was mostly sandy. At a 2.5% level of trisodium citrate, the product was smooth in consistency and was almost comparable to cheese foods with 3.0% trisodium citrate.

Standardized processed cheese foods

A number of processed cheese foods were prepared by replacing 20% cheese solids with WPC (26.1). Trisodium citrate in dry form was added at 2.5 and 3.0% level and

the moisture content in the final product maintained between 41.8 and 49.5%. It was observed that the consistency score of ≈ 6 was obtained at about 45.2 and 46.5% moisture content in processed cheese foods prepared with 2.5 and 3.0% trisodium citrate respectively (fig 2). At higher or lower moisture content than this, the consistency scores were low.

Comparative sensory quality of standardized processed cheese food with commercial processed cheeses

The standardized processed cheese food prepared with 2.5% trisodium citrate and 20% WPC solids scored much better over NDRI processed cheese from India and 3 Kraft processed cheeses (Kraft sliced Chester, 45% fat; Kraft cream, 50% fat, and Kraft Velveta, 20% fat in dry matter (DM)), from the German market (table V). The product scored slightly better than even the control processed cheese. All the sensory indices of cheese foods were between 5.5 to 6.0 out of 7, showing their good to very good acceptability. NDRI processed cheese lacked typical cheese flavour and had hard, crumbly and slightly mealy consistency. All Kraft cheeses also lacked typical cheese flavour and had a very soft body. Amul processed cheese from India, because of its rich flavour and smooth and firm consistency, scored best (6.0) in all sensory indices.

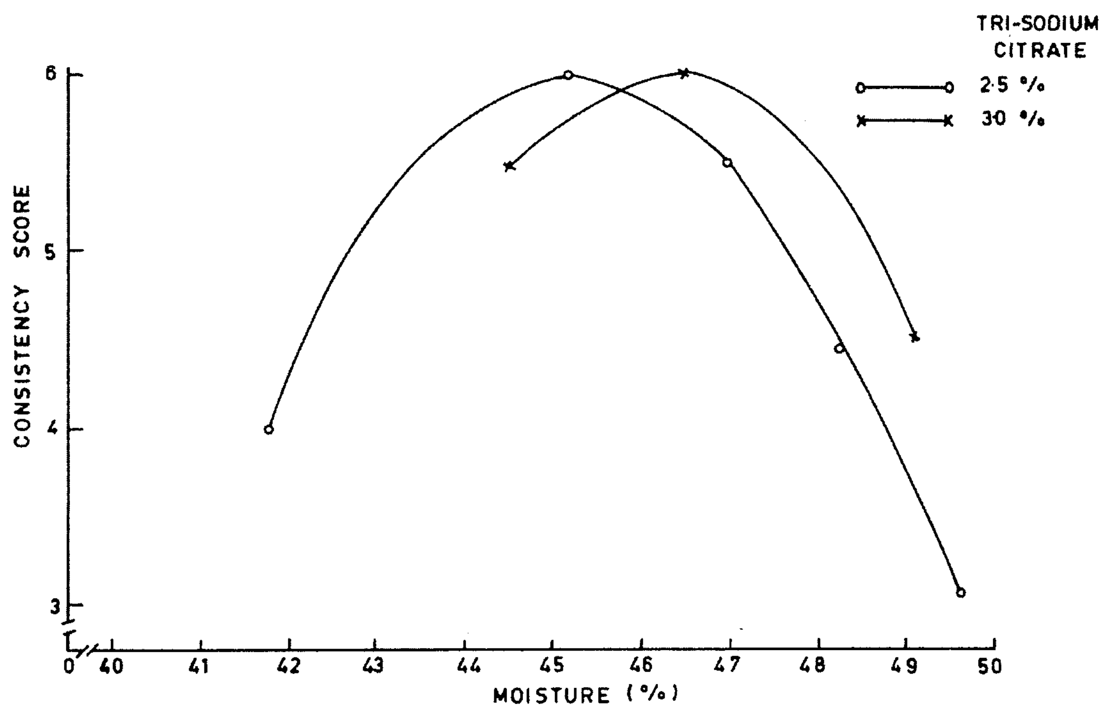

Fig 2. Consistency score of processed cheese foods as affected by different amounts of trisodium citrate and moisture.

Consistence des fromages fondus suivant la teneur en citrate trisodique et l'humidité.

Table V. Comparative sensory scores of processed cheese food and commercial processed cheeses.
Comparaison des scores sensoriels du fromage fondu expérimental par rapport à ceux du commerce.

Characteristics	*Processed cheese food*	*Control processed cheese*	*Amul*	*NDRI*	*Kraft sliced Chester (45% fat in DM)*	*Kraft cream (50% fat in DM)*	*Kraft Valveta (20% fat (in DM)*
Moisture (%)	45.2	41.3	45.4	41.8	48.4	50.8	59.4
Flavour	5.5	5.1	6.0	3.2	3.1	4.1	4.0
Consistency	5.8	5.4	6.0	4.1	4.1	5.2	4.2
Appearance	5.8	5.0	6.0	5.9	3.2	5.1	4.1
Overall acceptability	5.6	5.3	6.0	4.2	3.5	5.1	4.1

DISCUSSION

Effect of different emulsifying salts

With the addition of WPC, the ratio of protein to fat in cheese becomes higher. In normal cheeses, where enough fat as well as water is present, one end of the protein will dissolve in the fat, the other end will dissolve in the water and a homogenous product will result. In the absence of sufficient fat, the excess or unemulsified protein separates into grainy or chalky water phase deposits (Shimp, 1985). One way to increase the available fat is to increase the degree of emulsification by adding emulsifying salts. This increases the total surface area of the fat without changing the amount of fat present.

Joha emulsifying salts have been used in the processed cheese industry in Europe with great success for over 60 years. At the moment, there are about 20 different Joha emulsifying salts available for different processed cheeses. However, in most factories only a few of these 20 different salts are used (Meyer, 1973). S-8 and S-10 are such emulsifying salts (Prokopek, 1986; personal communication). It may be possible to obtain good quality cheese food with some combination of Joha salts, but the main difficulty with these salts is that their formulations are kept secret by the company. Failure of S-8 and S-10 Joha salts and combination of trisodium citrate and disodium phosphate emulsifying salts indicated that they could not increase the emulsifying power of fat sufficiently to take care of all the proteins in the system. The sandiness and chalkiness in cheese foods are probably due to the separation of unemulsified proteins.

In the Stephan Universal Machine, it is possible that the homogenizing effect produced by high speed rotating knives may have increased the surface area of fat. This, combined with high moisture content, might have helped in the improved emulsificaton of proteins.

The better results obtained by using trisodium citrate as compared to other emulsifiers in the present study supports the earlier findings of a number of workers (Templeton and Sommer, 1930, 1932; Gupta *et al*, 1984) that sodium citrate was a better emulsifier than disodium phosphate. It is possible that the addition of this emulsifying salt increased the surface area of fat to a greater degree.

Effect of different WPC

With the increase in UF concentration of whey, protein, fat, ash and calcium content on a DM basis are increased in WPC (Hiddink *et al*, 1981; Gupta and Reuter, 1987). So, with the use of WPC with higher total solids, greater amounts of these constituents are incorporated into processed cheese foods. For a greater amount of protein and calcium, better emulsifying action is required in the processed cheese food systems for smooth consistency. Diafiltration of WPC further increases its protein and calcium content (Gupta and Reuter, 1987). The emulsifier has to retain calcium, solubilize protein and increase hydration and swelling to facilitate emulsification of fat during processing (Caric *et al*, 1985). As the amount of calcium phosphate is increased, the solubility of casein in water is decreased and so is its emulsifying capability. With higher UF concentration, which is necessary for greater incorporation of WPC solids in processed cheese foods without undue increase in moisture, increased protein content in WPC is inevitable. But the calcium content can be kept low with suitable preheating

and UF conditions (Gupta and Reuter, 1987; Hiddink *et al*, 1987) as in the case of WPC (26.1), which resulted in better quality processed cheese food.

Effect of different moisture content

Higher amount of WPC incorporation introduces more whey proteins in processed cheese foods and thus there is more intense emulsification in the system. This increased WPC addition appears to be responsible for the firmer body of processed cheese foods. Olson and Price (1961) also reported the increase in firmness of processed cheeses with the increase of nonfat solids to moisture in the system. In the present investigation, increased moisture content might be countering the firming effect of increased WPC in processed cheese foods.

Effect of different levels of trisodium citrate

A minimum amount of trisodium citrate emulsifier has to be added to processed cheese foods to increase the surface area of fat in order to emulsify all the available proteins for smooth consistency of the product. Excess addition of emulsifier should be avoided, as it will not only result in more intense emulsification, but also incur extra cost.

Standardized processed cheese food

Lesser amount of emulsifier should produce less intense emulsification and a softer body in processed cheese foods. Therefore, a lower moisture content at a low level of emulsifier addition should result in a desirable product consistency.

Comparative sensory quality of processed cheese food with commercial processed cheese

Whey proteins are highly nutritious and contain a greater amount of sulphur-containing amino acids. During heat processing, these proteins become denatured and sulfhydryl groups are released which impart a heated or cooked flavour on heating (Parry, 1974). These flavours might enhance the flavour of processed cheese foods. Otherwise, the cheese flavour may have become diluted with the addition of non-cheese ingredients to the formulation. Processed cheeses in Germany are mostly of spreadable consistency, while Indian cheeses are mostly block type. Comparison of these cheese may not be very valid as preferences exist for all varieties of cheeses throughout the world. However, this comparison clearly shows the good quality of standardized processed cheese foods.

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